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Introduction

Severe injury to the sternoclavicular joint is rare. In children, less than 1% of fractures occur at the medial end of the clavicle [1]. Medial epiphyseal separation (dislocated Salter/Harris type I or II injury) of the clavicle is a characteristic injury of the growing skeleton [1]. Since there are only few reports dealing with this type of injury we would like to add our experience of six children to the literature, with particular emphasis on diagnosis, treatment, and outcome.

Material and methods

We retrospectively reviewed the data of our six patients with a so-called sternoclavicular dislocation diagnosed between 1993 and 1997. We focused on mechanism of injury, clinical manifestation, radiographic diagnosis, therapeutic management, intraoperative diagnosis, and results at follow-up.

Primary assessment consisted of clinical examination and standard radiography of the clavicle. Special views (Heinig [2]), occasionally supplemented by a panoramic view of the shoulder girdle, were obtained either primarily or with some delay depending on whether the condition was initially suspected or not. In two cases retrosternal dislocation of the clavicle was investigated by supplementary CT (using intravenous contrast in order to see vascular compression).

Closed reduction was attempted in all cases under general anesthesia with the patient in the supine position. Retrosternal displacement was reduced with the patient in the beach chair position with a sandbag placed between the scapulae. Backward traction was applied to shoulder and arm of the affected side, with the arm abducted. Using a towel clamp, the medial end of the clavicle was grasped and pulled forward. If reduction was clinically successful, a figure-of-eight bandage was applied. Reduction of anterior displacement was primarily attempted by a combination of direct backward pressure onto the displaced medial end of the clavicle and axial traction on the abducted arm.

If closed reduction failed, surgical treatment consisted of open anatomical reduction and internal fixation by nonabsorbable suture material as proposed by Simurda [3] or by a Vicryl sling placed around the first rib. A figure-of-eight bandage was applied postoperatively.

Functional, cosmetic, and radiological outcome was assessed in the outpatient clinic. In three patients, follow-up assessment of the sternoclavicular joint was performed by magnetic resonance

Table 1 Data of patients pertinent to injury, diagnosis and treatment

Patient	Accident	Symptoms	Diagnosis	Treatment	Remarks
T.H., girl, 15 years old	Fall from bicycle on left shoulder	Pain, local swelling, dysphagia next day	Salter/Harris II fracture with posterior displacement	Closed reduction	Diagnosis initially missed
W.T., boy, 10 years old	Fall from skateboard on left shoulder	Pain, local swelling. Mild dysphagia	Posterior displacement	Closed reduction	Diagnosis initially missed
A.E., boy, 8 years old	Fall on left shoulder	Pain, local swelling	Epiphyseal separation with posterior displacement	Open reduction and internal fixation (Simurda)	Diagnosis confirmed intraoperatively
S.M., boy, 10 years old	Fall on right shoulder	Pain, local swelling, dysphagia next day	Epiphyseal separation with anterior displacement	Open reduction and internal fixation (Vicryl band around first rib)	Diagnosis confirmed intraoperatively
K.B., girl, 6 years old	Motor vehicle accident as passenger	Pain local swelling	Salter/Harris II fracture with anterior displacement	Open reduction and internal fixation (Vicryl band around first rib)	Diagnosis confirmed intraoperatively
C.N., girl, 8 years old	Fall from bicycle on right shoulder	Pain, local swelling, dysphagia after eduction and redislocation	Salter/Harris II fracture with anterior displacement	Open reduction and internal fixation (Simurda)	Diagnosis confirmed intraoperatively. Redislocation after closed reduction

imaging (MRI) using T1- and T2-weighted series in coronal and oblique axial directions, each of them in a plane perpendicular to the clavicle.

Results

Three girls and three boys with Salter/Harris type I or II injury of the medial aspect of the clavicle were treated. The mean age of the patients was 10.2 years (range 8–15 years). The patient data pertinent to the injuries are shown in Table 1. In five children the mechanism of injury was an indirect backward or forward force upon the medial end of the clavicle by falling on the ipsilateral shoulder. One girl was similarly hurt as a passenger in a motor vehicle accident. All injuries were solitary and the consequence of low-impact trauma. Initial symptoms were local pain, aggravated by movement of the ipsilateral upper extremity, and local soft tissue irregularity due to displacement of the clavicle and/or additional swelling. One patient presented with dysphagia initially and three others developed dysphagia within the following 24 h.

Epiphyseal separation with posterior clavicular displacement was diagnosed in three children. In one patient, symptoms raised suspicion of the diagnosis and prompted the appropriate radiographic projection (as described by Heinig), yielding the correct diagnosis (Fig. 1a). In two, the diagnosis was missed at the initial physical and radiological examination (Fig. 2a). Persistent symptoms then led to the adequate radiological technique and correct diagnosis. CT confirmed the diagnosis in two of the three children with retrosternal clavicular displacement and revealed no further injuries (Fig. 3a,b).

In the three cases with anterior displacement of the clavicle, the diagnosis was suspected immediately and confirmed by the appropriate radiographs. CT was performed in all of these cases and revealed no further abnormality.

Closed reduction under general anesthesia in the three cases with retrosternal dislocation was successful in two (Figs. 1b, 2b). One patient with posterior clavicular displacement and all three with anterior displacement needed open reduction and internal fixation because of unstable reduction. A figure-of-eight bandage was applied for 3–4 weeks in all cases. The postoperative course was uneventful in all children.

In two patients with posterior displacement a postoperative CT confirmed anatomical reduction (Fig. 3c). Callus formation was observed in five out of six children who underwent radiographic follow-up evaluation after 4 weeks (one child had no late postoperative radiological studies). The time to follow-up assessment ranged from 2 months to 6 years (mean 4 years). Functional results were excellent in all patients, with full range of motion, unrestricted sport activity, and no pain. The four patients who had undergone open reduction developed disturbing hypertrophic scars, one of them requiring scar revision.

In two patients with posterior and one patient with anterior displacement MRI imaging was performed as long-term follow-up assessment (5–6 years after injury) and showed normal sternoclavicular anatomy.

Discussion

The temporal dynamics of skeletal maturation of the sternoclavicular joint are crucial for an understanding of the mechanism of injury in medial sternoclavicular

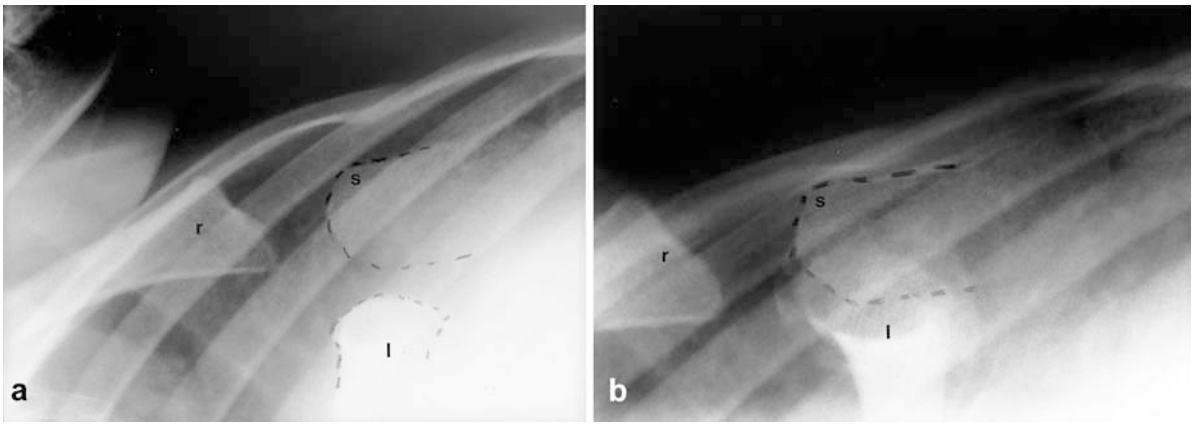

Fig. 1a, b Left posterior sternoclavicular dislocation. Right to left cross-table lateral X-ray ("Heinig projection") with left arm alongside chest demonstrates retrosternal dislocation of left clavicle (l) before (**a**) and normal sternoclavicular superposition after (**b**) reduction. Sternum (*s*); right clavicle (*r*) with ipsilateral arm elevated. (A.E., 8-year-old boy)

separation. The epiphysis of the medial end of the clavicle remains cartilaginous until the age of about 18 years, at which time the center of ossification forms [2]. Fusion does not occur until the age of 22–25 years [2]. It is well known that up until the time of fusion, the growth plate (physis) is the weakest part of a joint, i.e., the part most likely to sustain a fracture [4]. For this reason, children and adolescents will typically demonstrate the Salter-Harris type I or II fracture while adults with completed skeletal maturation will characteristically present with a true sternoclavicular dislocation [5].

The fracture diagnosis was unequivocally confirmed in four patients who underwent open reduction. Interestingly, conventional radiography could not distinguish between fracture and dislocation, and even on CT we initially misinterpreted the clavicular metaphyseal displacement as sternoclavicular dislocation. With the "inside" information from surgery, the Salter-Harris type II injury was recognizable retrospectively on CT in two patients (Fig. 3C). Moreover, the extensive callus formation found in all our patients was perfectly consistent with former fracture, but not with dislocation. A recent report claiming that true posterior sternoclavicular dislocations may occur in children [6] failed to produce sufficiently convincing evidence to support that statement.

Correct diagnosis is imperative in view of the operative treatment. The ligaments stabilizing the sternoclavicular joint attach at the epiphysis and the thick periosteum of the clavicle as long as the physeal plate remains open [2]. Therefore, in posterior displacement of the clavicle, the intact anterior periosteum and ligaments provide sufficient support for the reduced metaphysis. This explains the successful closed reductions in our series as well as in other reports [6, 7]. In contrast, anterior displacement is always associated with disruption of the anterior periosteum, resulting in a complete lack of structures holding the reduced metaphysis in place.

While anterior displacement is easily detected clinically, posterior displacement may be missed unless there is a high index of suspicion.

Most importantly, conventional radiological views of the clavicle are not usually diagnostic [8, 9]. In our experience, chest films and panoramic views of the shoulder girdle are more likely to disclose anterior than posterior displacement. Special projections (Heinig) allow correct diagnosis but require technical skill.

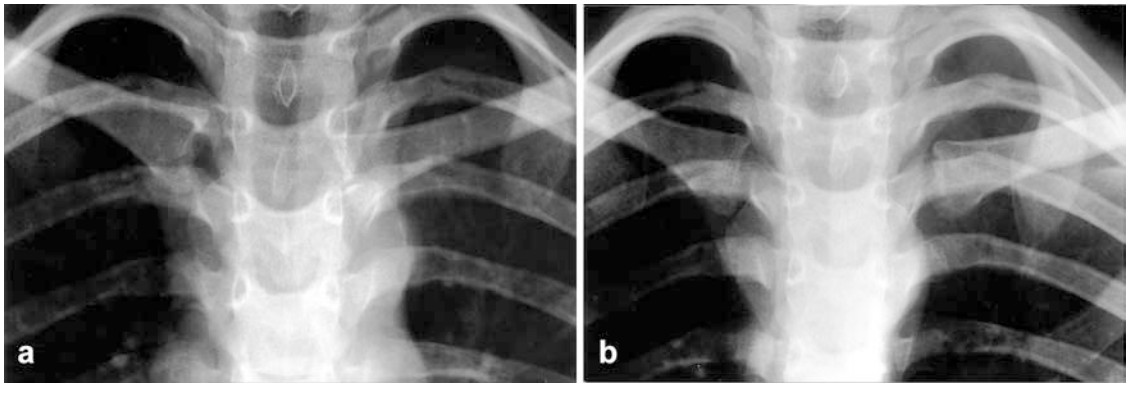

Fig. 2a,b Left posterior sternoclavicular dislocation. **a** Anteroposterior X-ray view of shoulder girdle (central part) shows medial end of left clavicle medially to left manubrium border (**a**); note abnormal closeness of the two medial clavicular ends. **b** Normalized relationship after reduction. (W.T., 10-year-old boy)

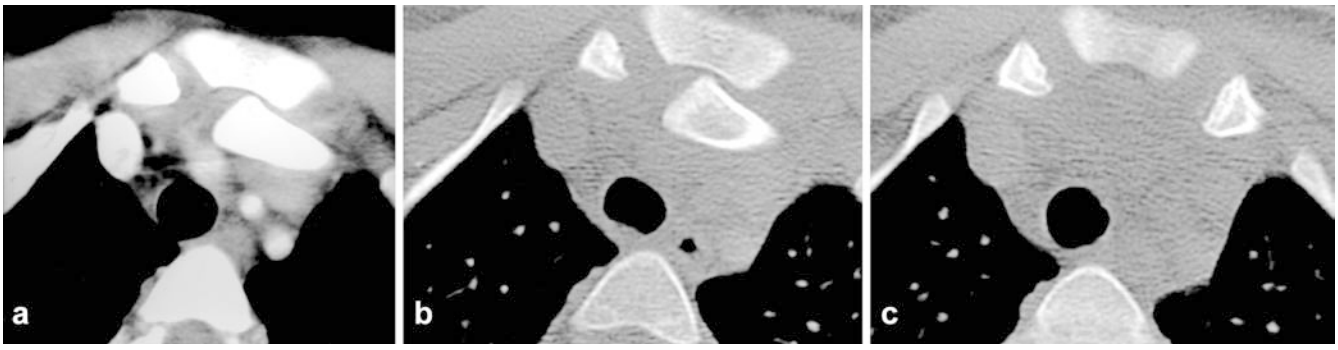

Fig. 3a–c Left posterior sternoclavicular dislocation. Axial contrast-enhanced CT scan through sternoclavicular region shows posterior and medial dislocation of clavicle behind upper sternum area; note reduced upper anterior mediastinal space causing dysphagia but no vascular compromise (**a** soft tissue window setting, **b** bone window setting). **c** Normalized sternoclavicular relationship after reduction; thin lamellar metaphyseal fragment indicates metaphyseal type 2 Salter lesion, not appreciated before open reduction. (T.H., 15-year-old girl)

Clearly, contrast-enhanced axial CT is the modality of choice in an emergency setting [10]. It also yields adequate information regarding neighboring structures, particularly the mediastinum, esophagus, trachea, and vasculature. MRI, if available, yields similar information and would in theory be ideal for the demonstration of cartilage anatomy and damage.

Treatment of both anterior and posterior displacement consists of reduction and retention. If the latter cannot be achieved by conservative means, surgical stabilization is warranted.

Reduction under general anesthesia is usually easy to perform. Closed reduction was successful in two of our three patients with posterior clavicular displacement. The third patient required open reduction and internal fixation because retention failed. In the largest pediatric series, 10 out of 12 patients underwent successful closed reduction as late as 5 days after trauma [7]. Since the functional and cosmetic results of closed reduction are usually perfect [6], primary open reduction and stabilization are not recommended. Conversely, open reduction and internal fixation must be performed in the relatively rare cases where conservative management fails [11].

Cases with anterior displacement usually require a different approach. Although easily reducible, retention is difficult if not impossible since complete disruption of the anterior capsule and, especially, the anterior sternoclavicular ligament commonly occurs [5], as it did in our three patients with anterior displacement. Thus, we suggest primary open reduction and internal fixation as proposed by Eskola [12]. The postoperative functional results of our patients were excellent. The only significant disadvantage of this approach is a potentially disfiguring hypertrophic scar.

Conclusions

In children and adolescents, a significant trauma to the medial end of the clavicle results in epiphysiolysis with presternal or retrosternal displacement of the clavicular metaphysis. The term ''sternoclavicular dislocation'' is, therefore, incorrect. The clinical diagnosis may be difficult and requires a high index of suspicion. CT is the method of choice for further radiological evaluation. Therapy consists of closed reduction in cases of posterior clavicular displacement, while anterior displacement requires primary surgery.

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